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Statement of

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Committee on Commerce, Science and Transportation
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Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to speak about NASA's technology development in support of the bold new aeronautics vision outlined by our Administrator, Daniel Goldin.

For the past 50 years we have been flying commercial transport aircraft that fairly closely resemble the Boeing 707, the first commercial jet transport, and we have been operating an air traffic control system based on centralized control concepts developed over 50 years ago. Significant advancements have been made to improve the performance and efficiency of 20th Century aircraft and our national airspace system over these five decades. Despite these enhancements, the public expects better performance and better performance is required to maintain and improve their quality of life. Our citizens want to fly more often, go to more locations, arrive on time, and be assured of improved safety and security. Airport neighbors want reduced noise and emissions. Businesses need affordable, on-time, secure delivery of freight virtually anywhere in the world.

Mr. Goldin has described both a bold new vision for the future of aeronautics in meeting these quality of life needs and a strategy for attaining this vision. He has presented a revolutionary approach to air traffic management and described a new perspective on revolutionary aerospace vehicles. The strategy he has set forth requires the simultaneous development of technologies to help improve the performance and safety of the existing aircraft and airspace traffic management system and technologies that achieve the longer-term visions he described.

The mission of the people at the NASA Research Centers is to turn these visionary possibilities into realities. Today, I want to tell you about some of the exciting new aeronautical technologies being developed at NASA that support the Administrator's vision for what NASA's aeronautics research can contribute to the Nation.

Langley Research Center (LaRC) is one of five NASA field centers providing the primary contributions to achieving the research goals of the Aerospace Technology Enterprise. Ames Research Center is focused on Information Technology, Glenn Research Center is focused on Power and Propulsion, Dryden Flight Research Center is focused on Flight Research, Marshall

Space Flight Center is focused on Space Launch Vehicles, and Langley Research Center is focused on Aerospace Vehicle Technologies for atmospheric flight. While the areas listed are their primary focus, all of the Centers are engaged in a broad range of research activities that support the agency goals.

I will concentrate on the research being done at Langley. The examples I will discuss are typical of the excellent work also being done at the other NASA Research Centers.

Langley Research Center Contributions to Quality of Life

As Director of the Langley Research Center, I am proud that our researchers are engaged in many research tasks that substantively contribute to the Nation's quality of life. They are studying the composition and evolution of Earth's atmosphere as an aid to policymakers, providing technologies for planetary exploration to extend the space frontier, working to reduce the cost of access to space, and helping assure the superiority of our military aircraft. The innovation inherent in Langley's efforts is underlined by the fact that the Center's researchers have been awarded over 200 patents in the last five years and have received over 30 of the prestigious "IR 100 Awards" given annually by the Research and Development magazine as one of the one hundred most-significant new technical products of the year. We, at Langley, also ensure that the benefits of our research are shared with non-aerospace firms and have licensed almost sixty technologies in the last few years.

The mission of the Langley research center is to take on long-term, high-risk, high-payoff technical aerospace challenges that are beyond the risk limit or capability of industry and to deliver validated technologies to address these challenges. The Administrator has provided a very challenging vision and our role at Langley and the other research centers is to turn it into reality. The vision he has articulated may seem very difficult to attain; however the scientists, engineers and technicians at Langley have never been afraid to tackle and master problems thought too difficult to solve and we welcome this challenge. An excellent example of this culture is seen in the Center's contributions to eliminating the impact of wind shear on aviation safety.

Wind shear is a spatially very concentrated and often very intense downward flow of air. From 1965 to 1985 this phenomenon was the most significant single factor responsible for aviation fatalities. Langley, in conjunction with the FAA, undertook a program to develop a sensor that could look out ahead of the aircraft and detect a wind shear with enough advance notice to enable the crew to fly around the hazard. At that time, the general view was that this problem was technically too tough to be solved. It was certainly beyond the risk limit of commercial enterprises. Nevertheless, in a relatively short time, sensors were developed, and using NASA's B-737 flying laboratory, the ability to detect wind shears and give the crew adequate warning to safely fly around the hazard was successfully demonstrated. There are now 4,000 aircraft worldwide using this technology. This is an example of the payoff of the research performed at the NASA Research Centers—a high-risk, high-payoff accomplishment brought into everyday use.

Military aircraft also directly benefit from our research. The F-18 E/F production was threatened when the aircraft exhibited "wing rock" (a severe un-commanded roll maneuver of the aircraft) during flight tests. The solution to this problem was a "porous wing fairing" which had been conceived and validated by researchers at Langley. When the F-18 E/F aircraft were retrofitted with this fairing, the "wing rock" was eliminated, thus avoiding a costly redesign or program cancellation.

Improving the Air Transportation System

Anyone who travels by air knows that our national air transportation system is approaching gridlock. Flight delays totaling three million hours were recorded in 1996. Studies indicate that those delays will rise to over 9 million hours by 2007 and to 25 million hours by 2017. In FY 2000, the National Business Travel Association estimated the annual cost of delays at $5 billion with a loss of 1.5 million work-hours. As time increasingly becomes the "scarce commodity" of the information age, the demand for aviation transportation is outpacing the capacity of today's hub-and-spoke system. Thus, when speed is at a premium, the nation's doorstep-to-destination travel speeds are getting worse, not better.

In accordance with the strategy expressed by the Administrator, research efforts at NASA are simultaneously addressing improvements to the existing system as well as trying to provide breakthrough system concepts that will change the air traffic management paradigm. Two technological improvements to the existing system are related to reducing the capacity-limiting aspects of wake vortices, and improving the capacity of airports in conditions of poor visibility.

Wingtip vortices – the turbulent wakes generated by an aircraft – can cause a loss of control by an airplane following too closely behind the aircraft generating the wake. A recent successful demonstration showed NASA's ability to predict both the strength and decay characteristics of aircraft wing tip vortices created during take-offs and landings. When this improved knowledge of wake vortex characteristics has been demonstrated to the level of certainty required for daily use in the air traffic management system, the spacing between aircraft can be safely reduced and capacity increased. Studies have shown that peak airport capacities could be increased between 6 percent and 12 percent depending on the specific mix of aircraft types at a given airport. This level of capacity increase is significant because of the leveraging effect between capacity changes and delays. When a system is operating near saturation, small changes in capacity result in very large changes in delay.

Many of the nation's busiest airports have closely spaced parallel runways. Under clear weather conditions aircraft using these runways can operate independently. As visibility decreases, aircraft cannot be seen well enough to ensure there will be no conflicts as a result of one of the aircraft departing from its appropriate flight path. In this situation, safety requirements demand controllers stagger the positions of aircraft operating on parallel runways. In some cases, operations using one of the runways are eliminated entirely. In either case, capacity is reduced. NASA's B-757 was used to demonstrate the technical feasibility of a system in each aircraft that senses the precise location of neighboring aircraft approaching on the closely spaced runways and issues appropriate warnings or evasive maneuver instructions to the flight crew as warranted by safety considerations. With this Airborne Information for Lateral Spacing technology in place, the reduction in capacity can be safely avoided.

The Ames Research Center has conceived, developed, and deployed many software support tools to aid air traffic controllers in obtaining improved capacity and traffic handling performance. These tools assist controllers in providing efficient runway surface operations and runway use, scheduling and metering aircraft into terminal areas at a rate that equals airport capacity, and sequencing and spacing arriving and departing traffic. They have been deployed and evaluated in the existing air traffic management system and have provided excellent support to the controllers in organizing and efficiently controlling the flow of aircraft. The tools are now being readied for more widespread application.

In addition to these improvements in the capacity of the existing Air Traffic Management System, we are participating in developing a breakthrough approach to provide enhanced mobility by utilizing this country's more than 5000 public use airports.

Small Aircraft Transportation System (SATS)

The past seven years of investment by NASA in small aircraft technologies coupled with changes in liability legislation have led to the emergence of a new generation of small aircraft. The NASA contributions to this new generation of safe and affordable aircraft were made through the Advanced General Aviation Transport Experiments (AGATE) Alliance and the General Aviation Propulsion (GAP) Program. The technologies developed, coupled with the Generation Aviation Revitalization Act of 1994 and with burgeoning market demand, have supported a dramatic industrial recovery over the past five years (1995-2000). The combined impact of these factors has resulted in more than a 300 percent growth in aircraft deliveries, more than a 350 percent growth in industry billings, over 20 percent improvement in fleet safety, recovery to about 20 percent of export deliveries, with about 10 percent annual growth of jobs in this sector.

New aircraft currently going into production have greatly benefited from NASA research. The aircraft include twin turbofan-powered, four- to six-place pressurized aircraft, and several new single-engine aircraft. These new aircraft possess near-all-weather operating capabilities and are compatible with the modernization of the National Airspace System. However, these new aircraft will not make the new transportation innovation fully available to the general public unless new concepts for airspace architecture and operations can be developed.

Fortunately, more than 98 percent of the U.S. population lives within a 30-minute drive of one of the over 5,000 public-use landing facilities. This infrastructure is an untapped national resource for mobility. The concept of a Small Aircraft Transportation System (SATS) offers a safe travel alternative, freeing people and products from transportation delays by creating access to more communities in less time. SATS is based on a new generation of affordable small aircraft operating in a fully distributed system of small airports serving thousands of suburban, rural, and remote communities. The safe, efficient utilization of smaller aircraft and smaller airports can provide a revolution in community accessibility and in public mobility. The system of enabling technologies can be developed and integrated to give the nation near-all-weather access to virtually every runway of these public-use facilities.

Today, small aircraft operating in airspace typical of small community airports are limited to "one-in, one-out" in low-visibility conditions. Air traffic controllers limit only one aircraft at a time in the airport vicinity due to the lack of both radar coverage and reliable communications. The SATS concept integrates high bandwidth wireless communications and Global Positioning System (GPS) technologies to enable multiple aircraft to land and takeoff at community airports. This capability will exist even under reduced visibility weather conditions, and without the need for expensive control towers and ground-based radar systems.

NASA is working with the FAA, industry, universities, and state and local governments to demonstrate the SATS concept. Once this concept is proven, we can work cooperatively with state and local governments to transition this capability across the nation to benefit all of our citizens. SATS technologies have the potential of reducing inter-city travel times by half in many markets, while increasing ten-fold the number of communities served by air transportation.

Improving Safety in the Air Transportation System

The worldwide commercial aviation major accident rate (as judged by hull losses per million departures) has been nearly constant over the past three decades. Although the rate is very low, increasing traffic over the years has resulted in the absolute number of accidents also increasing. The worldwide demand for air travel is expected to increase even further over the coming 2 decades—doubling or tripling by 2017 with the estimated requirement for up to $1 trillion in new aircraft deliveries. Without an improvement in the accident rate, such a traffic volume could lead to 50 or more major accidents a year—a nearly weekly occurrence. Given the very visible, damaging, and tragic effects of even a single major accident, this large number of accidents would clearly have an unacceptable impact upon the public's confidence in the aviation system and impede the anticipated growth of the commercial air-travel market. The safety of the general aviation (GA) system is also critically important. The current GA accident rate is many times greater than that of scheduled commercial transport operations. With the GA market also poised to grow significantly in future years, safety considerations must be removed as a barrier if this growth is to be realized.

As is the case in system capacity, NASA has ongoing research in safety enhancing technologies for nearer term application in the existing air traffic system as well as more revolutionary technologies for improving safety. In the last calendar year, LaRC demonstrated several capacity and safety related technologies at the Dallas Fort Worth (DFW) airport.

Runway incursions, which are conditions where two aircraft are operating on the same runway, are a growing national concern. Incursions have more than doubled over the past 6 years. Last year, we saw a new high of 429 recorded runway incursion incidents. A technology demonstration in October 2000, at the Dallas Fort Worth Airport, illustrated new methods to eliminate two-thirds of these incursions, specifically those caused by pilot errors. If made reliable enough to warrant installation on aircraft, these methods would allow the crew to positively and independently verify which runway they were on and indicate the presence of any other aircraft either on, or about to use, that runway. This capability would go a long way to eliminate the serious threat of, and the tragedy resulting from runway incursion accidents.

A more revolutionary approach to improving safety involves providing a synthetic vision system for the pilot. Limited visibility leading to controlled flight into terrain is one of the greatest contributing factors in fatal airline and general aviation crashes. Last October, again using NASA's B-757, an early version of a synthetic vision system was demonstrated at the Dallas Fort Worth Airport. This type of system would use terrain data maps and, eventually, fog-cutting sensors to give the crew a clear-weather view of the world outside the cockpit no matter what the weather or time of day and thus eliminate controlled flight into terrain accidents. One evaluation pilot commented during a demonstration flight, "The terrain picture -- the synthetic vision display -- is just terrific. I find myself forgetting that that's not the real world I'm looking at." While a significant amount of effort is still required to make these systems a reality, they do represent a breakthrough for safe flying.

Reducing noise

The projected increase in demand for air travel, coupled with our citizens' quality of life expectations require significantly improved aircraft noise reduction technologies. NASA's noise reduction program is focusing on three technical areas: engines, airframes such as landing gear and flaps, and aircraft operations. Major strides have been made in new approaches to reducing engine noise.

Not long ago, during the 1990's, as research limiting engine noise was being accomplished, airframe noise, the noise that the airframe itself makes as it moves through the air, was thought to be a barrier that would limit further overall aircraft noise reduction progress. Researchers at Langley and Ames took up this very difficult challenge, developed an understanding of the fundamental flow characteristics leading to the generation of airframe noise, and are now able to identify design modifications to substantially reduce airframe noise.

We have made significant progress, but public expectations are high, and our job is not done. NASA's ultimate goal is to develop technology to contain all objectionable noise within the airport boundaries. In this way we can achieve our citizens' expectations for their quality of life, for quiet neighborhoods and homes. Containing objectionable noise within the airport boundary will also enable the projected demand-driven increases for air travel to allow our citizens full access to all of the goods and services provided by our air transportation system.

Revolutionary New Vehicles for a New Era in Flight

Revolutionizing the airspace system alone is not enough. To meet the challenges of safety, noise, emissions and performance an entirely new level of vehicle efficiency, functionality and environmental compatibility must be achieved.

We stand at a unique time in technology evolution--a time where numerous advanced technologies have been developed or are on the horizon that will break the current "*tube with wings*" shape paradigm for aircraft. The significant advances in biotechnology, nanotechnology, and information technology are opening the door to a new era in aircraft development resulting in designs that will be radically different from today's aircraft. The continued viability of aviation is not through evolutionary or near-term approaches alone, but through development of revolutionary advances utilizing these emerging technologies.

As Mr. Goldin has pointed out, the aircraft of the future will not be built of traditional, multiple, mechanically-connected parts and systems. Instead, aircraft wing construction will employ fully integrated, embedded, "smart" materials and actuators that will operate more like a bird's wing. If we can emulate the characteristics present in nature, then we will be able to use these characteristics to develop revolutionary civil and military aircraft.

Rather than optimizing the vehicle shape for just one phase of flight (perhaps with some mechanical motion to achieve enhanced performance at a limited number of other conditions) we could have an aircraft which, like a bird, constantly changes its shape to achieve optimal performance at all flight conditions. Able to respond to the constantly varying conditions of flight, sensors will act like the "nerves" in a bird's wing and will measure the pressure over the entire surface of the wing. The response to these measurements will direct actuators, which will function like the bird's wing "muscles". Just as a bird instinctively uses different feathers on its' wings to control its' flight, the actuators will change the shape of the aircraft's wings to continuously optimize flying conditions.

Intelligent systems composed of sensors, actuators, microprocessors, and adaptive or neural controls will provide an effective "central nervous system" for stimulating the structure to effect an adaptive "physical response." The central nervous system will provide many advantages over current technologies. Proposed 21st Century aerospace vehicles will be able to monitor their own environment, performance, and even their operators in order to improve fuel efficiency, minimize airframe noise, and enhance safety. They will also have systems that will provide safe takeoffs and landings from short airfields enabling access to this country's more than 5,400 rural/regional airports.

Researchers at NASA Langley Research Center are exploring these advanced vehicle concepts and revolutionary new technologies.

New materials, actuators, and sensors

Langley Research Center has made pioneering contributions in composite technology development. We have recently initiated research activities on the development of nanostructured and biologically inspired material concepts. These new classes of materials have the potential to mimic the attractive attributes of biological systems including self-assembly, self-diagnostics, self-repair, and multi-functionality. The emergence of computational material analysis capabilities will give engineers the ability to design materials to achieve the desired functionality leading to ultra-lightweight, structurally efficient aerospace vehicles. Using physics-based computer simulations, Langley researchers have shown that carbon nanotube reinforced composites have the potential to be three times stronger and four times stiffer than even the composite materials used on aircraft such as the B-2 stealth bomber and the Boeing 777. Such new materials could reduce the vehicle structural weight by about 50 percent and the required fuel by about 25 percent. The gains in a next generation reusable launch vehicle would be even more dramatic because the new nanotube reinforced composite material would be replacing conventional aluminum. In this case the predicted vehicle dry weight could be reduced by a factor of four. These materials are an enabling technology for developing a single stage to orbit reusable launch vehicle, which is essential in achieving the goal of reducing space launch cost by an order of magnitude.

All flying vehicles rely heavily on effective sensing systems to ensure the safety and control of the vehicle. Thus far we have developed fiber optic sensors that can be embedded throughout large areas of the aircraft skin for health monitoring. Recent breakthroughs in this sensing technology has allowed us to put hundreds of sensors on a single optical fiber and sense a spectrum of stimuli including temperature, loads, and the presence of hazardous chemicals. These fiber optic sensors have been deployed on several large structures including X-33 prototype cryotanks and full scale wing box test structures. For a recent wing box load test 3000 fiber optic strain sensors on only four optical fibers were used to provide high-density strain data over a large area with negligible weight penalty. Thus we are able to reduce the weight and complexity of sensing systems while increasing the number of places on the vehicle we can make measurements. We have also designed fault tolerant systems that are impervious to electromagnetic interference. These technology advances are poised for integration into an advance aircraft control system that mimics the human central nervous system. In addressing our future vision, we are developing concepts that will combine these technologies into an advanced control system that can respond to sensed stimuli and seamlessly adapt the vehicle to unexpected flight conditions.

In addition to sensing systems, aerospace vehicles also rely upon actuators for vehicle control. Langley researchers have used smart materials to develop embeddable actuators that can be used to control aerodynamic and structural motion. Two such actuators "Thunder" and the "MicroFiberComposite" actuators have won IR 100 awards. In the area of innovative structural control, we expanded the performance envelope of engines by developing structural concepts that change shape using advanced smart metals to reduce fuel burn and cost. We have also used Langley developed piezoelectric materials to control vibration on an F-18 model resulting in increased service life and reduced cost. For the future we are currently developing new smart materials that can be used to control and move the aircraft structure on command to continually optimize performance throughout flight.

Aerodynamic Performance

To improve aerodynamic efficiency Langley engineers have conceived and demonstrated concepts for “porous” wings and small riblets on wing skins to dramatically reduce drag and improve performance. We have conceived new innovative concepts that allow us to effectively re-shape the wing of an airplane using micro devices to create a virtual new wing shape – one formed by both air flow and hardware. This micro-flow-control technology can improve the performance of aircraft engines, wings, and tails.

Langley has pioneered research in microflow control technology. Riblets are micro-grooves on a surface, which when aligned with the flow, can reduce the skin friction drag. This technology was flight-verified for a 6 percent reduction in skin friction drag. Another technology called Passive porosity allows the skin to breathe and redistributes the pressure field to potentially control flow separation for improved maneuvering capability. The U.S. Navy used this technique on the F-18E/F to solve its’ wing drop phenomenon. Micro-vortex generators (MVG’s) are small wing surface devices that energize the flow near the surface to help prevent flow separation. Test results showed that MVG’s dramatically enhanced aerodynamic performance including a 10-percent increase in lift, 50-percent decrease in drag, and a 100-percent increase in lift-to-drag ratio. During flight tests conducted in 1996 and 1997 by Gulfstream, the micro-vortex generators outperformed conventional vortex generators, and Gulfstream now incorporates MVG's on the outboard upper surfaces of its’ airplane wings for enhanced cruise performance. With the MVGs installed, the Gulfstream V was able to achieve a higher maximum cruise speed, extend its operational range capability, and exhibit better controllability. The Gulfstream V aircraft has set numerous domestic and world speed and performance records and was named the winner of the 1997 Collier Trophy presented by the National Aeronautic Association.

New technologies are currently being pursued in active microflow control. Microactive flow control is a very multi-disciplinary integration of technologies including advanced aerodynamics, smart materials, advanced structural integration, and new system control theory. In the past flow control has utilized steady actuation techniques such as steady blowing or suction. Further advances are possible by utilizing pulsed or unsteady actuation devices. Unsteady devices allow aerodynamicists to accomplish the same performance benefits as steady devices at two orders of magnitude less energy consumption. An example of an active flow-control device is the synthetic jet, a device that acts like a tiny electrically driven pump. It consists of a vibrating membrane placed in a chamber below the wing surface. These devices can be very small and operate on the micro-scales of the vehicle to achieve macro-scale results. As an enabling technology, active flow control technology benefits have not yet been fully explored. Langley is considering a variety of areas to apply these technologies to enable vehicles such as that portrayed in the NASA vision. These include active flow control in engine inlets to improve efficiency and reduce noise, new concepts for pneumatic flaps or ailerons to eliminate the need for existing high-lift or flight control surfaces. Other applications include drag reduction concepts, noise reduction concepts, and flight-maneuverability concepts.

High Speed Flight

The value of time as a commodity is also evident in air travel over long distances. Intercontinental travel at current commercial transport speeds can be grueling and potentially unhealthy. The investments made to date by the U.S. government and industry have made the dream of a environmentally acceptable, economically viable supersonic aircraft nearly a reality. NASA is cooperating with DARPA to explore noise reduction technologies and low sonic boom designs. Langley engineers have also explored modifying the physical shape of the aircraft utilizing numerical optimization. These optimized vehicles demonstrate improved aerodynamic efficiency, and much lower sonic boom levels at supersonic speed. Continued effort is needed to explore new technologies in these areas, and others including improved efficiency and longer aircraft life.

Technology Integration

Although I've addressed four technological areas separately, the technological advances in one area often beneficially affect other technology areas. By integrating advanced technologies we feel that more efficient and adaptable aircraft are in our reach. This year we are conducting tests to demonstrate simplified flaps on aircraft using small synthetic jets with smart materials to control the flow over the wings. This technology blends advanced materials, control systems, micro electronics, and aerodynamics to enable shorter take off and landing, lighter weight flaps, and reduced fuel burn and noise. In the next several years we look forward to demonstrating concepts for dramatically improving the safety of aerospace vehicles using self-healing materials and electrical systems. We envision aircraft that are optimized to improve functionality for the entire flight regime specifically addressing safety needs while reducing fuel burn and noise. These technological advancements will benefit the breadth of flight vehicles from vehicles that fly in the atmosphere to space transportation vehicles.

Achieving the Goals

NASA's vision for revolutionizing air traffic management and developing revolutionary new aerospace vehicles is sufficiently ambitious to undoubtedly cause some to wonder whether or not it is achievable. Efforts of this level of difficulty represent the proper role for NASA, which is to undertake activities beyond the risk limit or capability of industry, and to deliver validated technologies. My belief is that the goals inherent in the vision are achievable. The belief is based on both on our long-term track record and on the recent, demonstrated progress made toward achieving our goals.

It is imperative that we aggressively pursue attainment of the technology advances required by the vision. The pace of technology development is increasing very rapidly and the only way to achieve world leadership in an area is to out run the competition. Moreover, one of the most effective ways to maintain and increase the quality of life for our Nation is to provide for the enhanced safety, efficiency and environmental compatibility of our air transportation system as quickly as possible. NASA is uniquely positioned to conduct the research required to develop revolutionary new air vehicles and a revolutionary new approach for air traffic management. We do not believe, as some might suggest, that these are maturing areas of technology. We believe that our 21st Century future is as full of promise today as was the 20th Century to our predecessors.

We are accomplishing excellent, high-payoff research activities that will benefit the quality of life in the country through enhancements in safety, airspace system capacity, noise and emission reduction and contributions to the pre-eminence of military aircraft.

Hard choices have been and are being made. The NASA Aerospace Technology Enterprise has reprogrammed a significant portion of its research funding to enhance efforts to achieve the highest priority products. The reprogramming efforts have taken place within our existing funding and have thus necessitated stopping some ongoing efforts. The agency is also emphasizing aerospace research rather than Aeronautics and Space activities to help achieve all the synergies that are available. The Agency has embarked on a detailed study to determine which facilities it requires for the future, to eliminate the facilities it no longer needs, and to ensure it has adequate funds to maintain and renew the facilities it requires

Hearings such as this one today will help the country with this debate, I am happy to have been able to contribute some input to the discussion.